smaller than 81 and the value of a/b is equal to or larger than 2.9 and equal to or smaller than 4.7, the apparatus being constituted so as to record data in the optical recording medium by determining the number of recording pulses having a level equal to a recording power at the time of forming a record mark having a length of n times one cycle of the reference clock to be $n/2$ when n is an even number and to be $(n + 1)/2$ or $(n - 1)/2$ when n is an odd number.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[FIELD OF THE INVENTION]

The present invention relates to an optical recording medium, and particularly, to a data rewritable type optical recording medium in which a phase change material is used as a material for a recording layer. Further, the present invention relates to a method and an apparatus for optically recording data in an optical recording medium, and particularly, to a method optically recording data in a data rewritable type optical recording medium in which a phase change material is used as a material for a recording layer and an apparatus optically recording data in such a data rewritable type optical recording medium.

[0002]

[DESCRIPTION OF THE PRIOR ART]

Optical recording media such as the CD, DVD and the like have been widely used as recording media for recording digital data. These optical recording media can be roughly classified into optical recording media such as the CD-ROM and the DVD-ROM that do not enable writing and rewriting of data (ROM type optical recording media), optical recording media such as the CD-R and DVD-R that enable writing but

not rewriting of data (write-once type optical recording media), and optical recording media such as the CD-RW and DVD-RW that enable rewriting of data (data rewritable type optical recording media).

[0003]

Data are generally recorded in a ROM type optical recording medium using pre-pits formed in a substrate in the manufacturing process thereof, while in a write-once type optical recording medium, an organic dye such as a cyanine dye, phthalocyanine dye or azo dye is generally used as the material of the recording layer and data are recorded utilizing changes in an optical characteristic caused by chemical change of the organic dye, which change may be accompanied by physical deformation.

[0004]

On the other hand, in a data rewritable type optical recording medium, a phase change material is generally used as the material of the recording layer and data are recorded utilizing changes in an optical characteristic caused by phase change of the phase change material. More specifically, since the reflection coefficients of the phase change material are different between the case where the phase change material is in a crystal phase and the case where it is in an amorphous phase, data can be recorded and reproduced utilizing these characteristics of the phase change material. For example, if a region of a recording layer where the phase change material is in a crystal phase is referred to as "a recording mark" and a region of the recording layer where the phase change material is in an amorphous phase is referred to as "a blank region", data can be expressed by the length of the recording mark, namely, the length between the front edge portion of the recording nark and the rear edge portion thereof, and the length of the blank region,

namely, the length between the rear edge portion of the recording mark and the front edge portion of a next recording mark.

[0005]

In the case where a recording mark is to be formed in a recording layer of a data rewritable type optical recording medium, a laser beam whose power is set to a recording power *Pw* having a sufficiently high level is projected onto the recording layer to heat a region of the recording layer irradiated with the laser beam to a temperature higher than the melting point of a phase change material and then, a laser beam whose power is set to a bottom power *Pb* having a sufficiently low level is projected onto the recording layer to quickly cool the region of the recording layer. As a result, the phase of the phase change material contained in the region of the recording layer changes from a crystal phase to an amorphous phase to form a record mark. On the other hand, in the case where a record mark formed in the recording layer of a data rewritable type optical recording medium is to be erased, a laser beam whose power set to the erasing power *Pe* having a level equal to or lower than the recording power *Pw* and equal to or higher than the bottom power *Pb* is projected onto the recording layer to heat a region of the recording layer where a record mark is formed to a temperature equal to or higher than the crystallization temperature of the phase change material and the region of the recording layer heated to the temperature equal to or higher than the crystallization temperature of the phase change material is gradually cooled. Thus, the phase of the phase change material contained at the region of the recording layer where the record mark was formed changes from an amorphous phase to a crystalline phase and the record mark is erased.

[0006]

Therefore, it is possible not only to form a record mark in the recording layer but also to directly overwrite a record mark formed in the region of the recording layer by modulating the power of the laser beam projected onto the recording layer between a plurality of levels corresponding to the recording power *Pw*, the bottom power *Pb* and the erasing power *Pe*.

[0007]

A chalcogen system alloy such as a GeSbTe system alloy, an AgInSbTe alloy or the like is known as a phase change material usable for a recording layer of a data writable type optical recording medium. A chalcogen system alloy containing Sb and Te has a high crystallization speed and is suitable as a phase change material for a recording layer of a data writable type optical recording medium in which data are recorded at a high speed. Of particular interest is that the crystallization speed of a chalcogen system alloy increases as the ratio of Sb to Te contained in the alloy increases. An optical recording medium whose recording layer contains such an alloy therefore enables recorded data to be directly overwritten at a high linear velocity.

[0008]

[PROBLEMS TO BE SOLVED BY THE INVENTION]

However, as the ratio of Sb to Te contained in a chalcogen system alloy increases, the crystallization temperature of the chalcogen system alloy decreases while the crystallization speed of the chalcogen system alloy increases and, therefore, the thermal stability thereof in an amorphous phase becomes lower. Specifically, in the case where the thermal stability of the chalcogen system alloy in an amorphous phase becomes lower, the storage reliability of the optical recording medium may be degraded because there is a risk of record marks being erased

when data are repeatedly reproduced from the optical recording medium or the optical recording medium is stored in a high-temperature atmosphere. In this manner, it is difficult to provide a data rewritable type optical recording medium that has improved high-linear-velocity data recording characteristics and is simultaneously improved in data reproduction durability and storage reliability.

[0009]

In order to provide a data rewritable type optical recording medium that has improved high-linear-velocity data recording characteristics and is simultaneously improved in data reproduction durability and storage reliability, it is effective to employ a material whose crystallization speed and crystallization temperature are high as a material for a recording layer. However, it can be considered that in order to achieve data recording at an extremely high linear recording velocity such as 14 m/sec, it is insufficient to select a material for a recording layer and it is necessary to further make the structure of an optical recording medium, namely, the layer configuration thereof so as to have excellent heat radiation characteristics.

[0010]

It is therefore an object of the present invention to provide a data rewritable type optical recording medium that has improved high-linear-velocity data recording characteristics and is simultaneously improved in data reproduction durability and storage reliability.

[0011]

On the other hand, in the case of directly overwriting data recorded in a data rewritable type optical recording medium, it is often to employ a divided pulse modulating method in which the power of a laser beam is increased to a recording power Pw more than once to form a

recording mark. For example, in a DVD-RW which is a kind of data rewritable type optical recording media, recording marks whose lengths correspond to 3T to 11T and 14T where T is a reference clock cycle are used and the number of recording pulses (how often the power of a laser beam is increased to a recording power Pw) is set to $(n-1)$ or $(n-2)$ to form a recording mark where n is the multiple number of T corresponding to a kind of recording mark and one of 3 to 11 and 14.

[0012]

However, it is necessary to set the reference clock cycle higher in order to record data in a data rewritable type optical recording medium at a higher linear recording velocity and since as the reference clock cycle becomes higher, time required for forming each of recording marks becomes shorter, it becomes difficult to modulate the power of a laser beam in accordance wit a number of recording pulses within a time period for forming a recording mark. In particular, in order to record data at an extremely high linear recording velocity such as 14 m/sec, it is necessary to set the reference clock cycle to a very high value equal to or higher than 150 MHz and in such a case, it is difficult to form a recording mark having a desired shape even in the case of employing a known divided pulse modulating method.

[0013]

It is therefore another object of the present invention to provide an improved optical data recording method and an improved data optical recording apparatus which can record data in a data rewritable type optical recording medium at an extremely high linear recording velocity.

[0014]

[MEANS FOR SOLVING THE PROBLEMS]

An optical recording medium according to the present invention is

characterized by comprising a recording layer, a first dielectric layer disposed on the side of a light incidence plane with respect to the recording layer, a second dielectric layer disposed on the side opposite from the light incidence plane with respect to the recording layer, a heat radiation layer disposed on the side of the light incidence plane with respect to the first dielectric layer and a reflective layer disposed on the side opposite from the light incidence plane with respect to the second dielectric layer, the recording layer containing a phase change material represented by an atomic composition formula: $Sb_aTe_bGe_cMn_d$, where the value of *a* is equal to or larger than 57 and equal to or smaller than 74, the value of *c* is equal to or larger than 2 and equal to or smaller than 10, the value of *d* is equal to or larger than 5 and equal to or smaller than 20, the value of $(a + d)$ is equal to or larger than 74 and equal to or smaller than 81 and the value of a/b is equal to or larger than 2.9 and equal to or smaller than 4.7.

[0015]

According to the present invention, since the recording layer is formed of the above identified material and the optical recording medium comprises a heat radiation layer, it is possible to improve high-linear-velocity data recording characteristics and simultaneously improve data reproduction durability and storage reliability. Thus, even if data are recorded in the optical recording medium at an extremely high linear recording velocity such as 14 m/sec or higher, it is possible to improve the data recording characteristics of the optical recording medium. Here, "a light incidence plane" means a surface of the optical recording medium onto which a laser beam for recording data or reproducing data is projected.

[0016]

Further, in order to reliably improve the data recording characteristics of the optical recording medium, it is preferable for the heat radiation layer to contain aluminum nitride (AlN) as a primary component and it is preferable for the reflective layer to be formed of silver (Ag) or an alloy containing silver (Ag). Moreover, it is preferable for the first dielectric layer to have a thickness of 10 nm to 40 nm and it is preferable for the second dielectric layer to have a thickness of 3 nm to 16 nm.

[0017]

Moreover, in the case where the phase change material contained in the recording layer and represented by the atomic composition formula: $Sb_aTe_bGe_cMn_d$ has such a composition that the value of *d* is equal to or larger than 11 and equal to or smaller than 20 and the second dielectric layer has a thickness of 3 nm to 12 nm, even when data are to be recorded in the optical recording medium at a linear recording velocity equal to or higher than 21 m/sec and equal to or lower than 33 m/sec, it is possible to improve the data recording characteristics of an optical recording medium. In particular, it is preferable for the phase change material contained in the recording layer and represented by the atomic composition formula: $Sb_aTe_bGe_cMn_d$ to have such a composition that the value of *a* is equal to or larger than 60 and equal to or smaller than 70, the value of *c* is equal to or larger than 2 and equal to or smaller than 10, the value of *d* is equal to or larger than 11 and equal to or smaller than 16, the value of $(a + d)$ is equal to or larger than 77 and equal to or smaller than 79 and the value of a/b is equal to or larger than 3.2 and equal to or smaller than 4.5 and in such a case, even if data are to be recorded by varying a linear recording velocity over an extremely wide range, namely, at a linear recording velocity equal to or higher than 14

m/sec and equal to or lower than 33 m/sec, it is possible to improve the data recording characteristics of an optical recording medium.

[0018]

Furthermore, in the case where the phase change material contained in the recording layer and represented by the atomic composition formula: $Sb_aTe_bGe_cMn_d$ has such a composition that the value of d is equal to or larger than 5 and equal to or smaller than 16, it is preferable for the optical recording medium to store recording condition setting information necessary for recording data at a linear recording velocity equal to or higher than 14 m/sec and equal to or lower than 21 m/sec and in the case where the phase change material contained in the recording layer and represented by the atomic composition formula: $Sb_aTe_bGe_cMn_d$ has such a composition that the value of d is equal to or larger than 11 and equal to or smaller than 20, it is preferable for the optical recording medium to store recording condition setting information necessary for recording data at a linear recording velocity equal to or higher than 21 m/sec and equal to or lower than 33 m/sec. Further, in the case where the phase change material contained in the recording layer and represented by the atomic composition formula: $Sb_aTe_bGe_cMn_d$ has such a composition that the value of d is equal to or larger than 11 and equal to or smaller than 16, it is preferable for the optical recording medium to store recording condition setting information necessary for recording data at a linear recording velocity equal to or higher than 14 m/sec and equal to or lower than 33 m/sec.

[0019]

Moreover, it is preferable for the optical recording medium to store recording condition setting information necessary for determining

the number of recording pulses having a level equal to a recording power at the time of forming a record mark having a length of n times one cycle of the reference clock to be $n/2$ when n is an even number and to be $(n + 1)/2$ or $(n - 1)/2$ when n is an odd number and it is further preferable for the optical recording medium to store recording condition setting information necessary for setting a ratio Pe/Pw of an erasing power of a laser beam Pe to a recording power Pw thereof to be equal to or larger than 0.26 and equal to or smaller than 0.51, thereby recording information therein. In these cases, it is possible to further improve the data recording characteristics of the optical recording medium.

[0020]

Furthermore, it is preferable for the optical recording medium to further comprise a substrate disposed on the side opposite from the light incidence plane with respect to the recording layer and a light transmission layer disposed on the side of the light incidence plane with respect to the heat radiation layer and wherein the reflective layer, the second dielectric layer, the recording layer, the first dielectric layer, the heat radiation layer and the light transmission layer are formed on the substrate. The optical recording medium having such a layer configuration is a so-called next generation type optical recording medium and the present invention can be preferably applied to the next generation type optical recording medium.

[0021]

Further, the method for optically recording data in an optical recording medium according to the present invention is characterized by being constituted so as to record data in an optical recording medium whose recording layer containing a phase change material represented by an atomic composition formula: $Sb_aTe_bGe_cMn_d$, where the value of a is

equal to or larger than 57 and equal to or smaller than 74, the value of *c* is equal to or larger than 2 and equal to or smaller than 10, the value of *d* is equal to or larger than 5 and equal to or smaller than 20, the value of (*a* + *d*) is equal to or larger than 74 and equal to or smaller than 81 and the value of *a*/*b* is equal to or larger than 2.9 and equal to or smaller than 4.7 and comprising a step of recording data in the optical recording medium by determining the number of recording pulses having a level equal to a recording power at the time of forming a record mark having a length of *n* times one cycle of the reference clock to be *n*/2 when *n* is an even number and to be (n + 1)/2 or (*n* – 1)/2 when *n* is an odd number.

[0022]

In the present invention, it is preferable to set a ratio *Pe*/*Pw* of an erasing power of a laser beam *Pe* to a recording power *Pw* thereof to be equal to or larger than 0.27 and equal to or smaller than 0.51 and set a linear recording velocity to be equal to or higher than 14 m/sec and lower than 21 m/sec, thereby recording data therein. In addition, it is also preferable to set a ratio *Pe*/*Pw* of an erasing power of a laser beam *Pe* to a recording power *Pw* thereof to be equal to or larger than 0.26 and equal to or smaller than 0.47 and set a linear recording velocity to be equal to or higher than 21 m/sec and lower than 33 m/sec, thereby recording data therein.

[0023]

The apparatus for optically recording data in an optical recording medium according to the present invention is characterized by being constituted so as to record data in an optical recording medium whose recording layer containing a phase change material represented by an atomic composition formula: $Sb_aTe_bGe_cMn_d$, where the value of *a* is equal to or larger than 57 and equal to or smaller than 74, the value of *c* is

equal to or larger than 2 and equal to or smaller than 10, the value of d is equal to or larger than 5 and equal to or smaller than 20, the value of $(a + d)$ is equal to or larger than 74 and equal to or smaller than 81 and the value of a/b is equal to or larger than 2.9 and equal to or smaller than 4.7 by determining the number of recording pulses having a level equal to a recording power at the time of forming a record mark having a length of n times one cycle of the reference clock to be $n/2$ when n is an even number and to be $(n + 1)/2$ or $(n - 1)/2$ when n is an odd number.

[0024]

[DESCRIPTION OF THE PREFERRED EMBODIMENTS]

Hereinafter, a preferred embodiment of the present invention will now be explained in detail with reference to accompanying drawings.

[0025]

Figure 1 (a) is a schematic perspective view showing an external appearance of an optical recording medium that is a preferred embodiment of the present invention and Figure 1 (b) is an enlarged schematic cross-sectional view of the part of the optical recording medium indicated by A in Figure 1.

[0026]

As shown in Figures 1 (a) and (b), an optical recording medium 10 according to this embodiment is formed disk-like and has an outer diameter of about 120 mm and a thickness of about 1.2 mm. As shown in Figure 1 (b), the optical recording medium 10 includes a support substrate 11 and a reflective layer 12, a second dielectric layer 13, a recording layer 14, a first dielectric layer 15, a heat radiation layer 16 and a light transmission layer 17 laminated on the support substrate 11 in this order. The optical recording medium 10 according to this embodiment is constituted as a data rewritable type optical recording

medium so that data can be recorded therein and reproduced therefrom by projecting a laser beam L having a wavelength of 380 nm to 450 nm, preferably about 405 nm onto a light incidence plane constituted by the surface of the light transmission layer 17. When data are to be recorded in and reproduced from the optical recording medium 10, an objective lens having a numerical aperture equal to or larger than 0.7, preferably about 0.85 is used and the wavelength λ of the laser beam and the numerical aperture NA of the objective lens are selected so that λ / NA is equal to or smaller than 640 nm.

[0027]

The support substrate 11 is a dick-like substrate serving as a support for ensuring a thickness of about 1.2 mm required for the optical recording medium 10 and having a thickness of about 1.1 mm. Grooves 11a and lands 11b are spirally formed on the surface of the support substrate 11 from a portion in the vicinity of the center of the support substrate 11 toward the outer peripheral portion thereof or from the outer peripheral portion of the support substrate 11 toward a portion in the vicinity of the center thereof for guiding a laser beam L. Although not particularly limited, the depth of the groove 11a is preferably set to 10 nm to 40 nm and the pitch of the grooves 11a is preferably set to 0.2 μm to 0.4 μm. The material used to form the support substrate 11 is not particularly limited and the support substrate 11 can be formed of glass, ceramic, resin or the like. Among these, resin is preferably used for forming the support substrate 11 since resin can be easily shaped. Illustrative examples of resins suitable for forming the support substrate 11 include polycarbonate resin, polyolefin resin, acrylic resin, epoxy resin, polystyrene resin, polyethylene resin, polypropylene resin, silicone resin, fluoropolymers, acrylonitrile butadiene styrene resin, urethane resin and

the like. Among these, polycarbonate resin and polyolefin resin are most preferably used for forming the support substrate 11 from the viewpoint of easy processing, optical characteristics and the like. In this embodiment, since the laser beam L is not projected onto the recording layer 14 via the support substrate 11, it is unnecessary for the support substrate 11 to have a high light transmittance property.

[0028]

It is preferable to fabricate the support substrate 11 by an injection molding process using a stamper but the support substrate 11 may be fabricated using another process such as a 2P process.

[0029]

The reflective layer 12 serves to reflect the laser beam L entering through the light transmission layer 17 so as to emit it from the light transmission layer 17 and effectively radiate heat generated in the recording layer 14 by the irradiation with the laser beam L. Further, the reflective layer 12 serves to increase a reproduced signal (C/N ratio) by a multiple interference effect. The material used for forming the reflective layer 12 is not particularly limited insofar as it can reflect a laser beam L. Illustrative examples of the materials used for forming the reflective layer 12 include magnesium (Mg), aluminum (Al), titanium (Ti), chromium (Cr), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), germanium (Ge), silver (Ag), platinum (Pt), gold (Au) and the like. Among these materials, it is preferable to form the reflective layer 12 using silver (Ag) or an alloy containing silver (Ag) as a primary component from the viewpoint of reflection coefficient and thermal conductivity. In this specification, the statement "an alloy containing silver (Ag) as a primary component" means an alloy containing 95 atomic % or more of silver (Ag). In the case where silver (Ag) or an alloy

containing silver (Ag) as a primary component is used as a material for forming the reflective layer 12, it is possible to form a reflective layer 12 having a high reflection coefficient with respect to a laser beam L and improve the heat radiation characteristics of a recording layer 14.

[0030]

It is preferable to form the reflective layer 12 to have a thickness of 20 to 200 nm and is more preferable to form it to have a thickness of 7 to 150 nm. In the case where the thickness of the reflective layer 12 is thinner than 20 nm, the above described effects cannot sufficiently be obtained. On the other hand, in the case where the thickness of the reflective layer 12 exceeds 200 nm, the surface smoothness of the reflective layer 12 is degraded and it takes a longer time for forming the reflective layer 12, thereby lowering the productivity of the optical recording medium 10. To the contrary, in the case where the thickness of the reflective layer 12 is set to 20 to 200 nm, in particular, in the case where the thickness of the reflective layer 12 is set to 7 to 150 nm, the above described effects can be obtained and it is possible to improve the surface smoothness of the reflective layer 12 and prevent the productivity of the optical recording medium 10 from being lowered.

[0031]

Here, in order to prevent the reflective layer 12 from being corroded, it is possible to form between the support substrate 11 and the reflective layer 12 a moisture-proof layer of a dielectric material. Illustrative examples of a dielectric material usable for forming a moisture-proof layer include oxide, sulfide, nitride or carbide of aluminum (Al), silicon (Si), cerium (Ce), titanium (Ti), zinc (Zn), tantalum (Ta) and the mixture thereof and the like such as Al_2O_3, AlN, ZnO, ZnS, GeN, GeCrN, CeO_2, SiO, SiO_2, Si_3N_4, SiC, La_2O_3, TaO, TiO_2,

SiAlON (mixture of SiO_2, Al_2O_3, Si_3N_4 and AlN), LaSiON (mixture of La_2O_3, SiO_2 and Si_3N_4) or the like. In the case where the moisture-proof layer is provided between the support substrate 11 and the reflective layer 12, it is preferable to form the moisture-proof layer of the mixture of ZnS and SiO_2.

[0032]

The recording layer 14 is a layer in which record marks are reversibly to be formed and the recording layer 14 is formed of a phase change material as described in detail below. The reflection coefficients of the phase change material are different between the case where the phase change material is in a crystal phase and the case where it is in an amorphous phase, and data can be recorded utilizing this characteristic of the phase change material. Data can be expressed by the length of the recording mark, namely, the length between the front edge portion of the recording nark and the rear edge portion thereof, and the length of the blank region, namely, the length between the rear edge portion of the recording mark and the front edge portion of a next recording mark. Each of lengths of a recording mark and a blank region is set as integral multiple of T where T is a length corresponding to that of one cycle of a reference clock and concretely, a recording mark and a blank region having each of 2T to 8T are used in the 1.7RLL Modulation Code.

[0033]

In the case of changing the phase of the phase change material contained in the recording layer 14 from the crystal phase to the amorphous phase, a laser beam L whose power is changed in accordance with a pulse waveform having an amplitude between a recording power Pw and a bottom power Pb is projected onto the light incidence plane 17a to heat the recording layer 14 to a temperature equal to or higher than

the melting point of the phase change material, thereby forming a melting region in the recording layer 14. Then, the laser beam L whose power is set to the bottom power Pb is projected onto the recording layer 14, thereby quickly cooling the melting region of the recording layer 14 to change the phase thereof to an amorphous phase. Thus, a record mark is formed at the region of the recording layer 14 whose phase is in an amorphous phase. On the other hand, the case of changing the phase of the phase change material contained in the recording layer 14 from the amorphous phase to the crystal phase, a laser beam L whose power is set to an erasing power Pe is projected onto the light incidence plane 17a to heat the recording layer 14 to a temperature equal to or higher than the crystallization temperature of the phase change material and the region of the recording layer 14 where is heated to the temperature equal to or higher than the crystallization temperature of the phase change material is gradually cooled by moving the laser beam L away therefrom. Thus, the region of the recording layer 14 is crystallized.

[0034]

Here, the recording power Pw, the erasing power Pe and the bottom power Pb are determined so that the recording power Pw is higher than the erasing power Pe and the erasing power Pe is equal to or higher than the bottom power Pb. Thus, if the power of a laser beam L is modulated in this manner, it is possible not only to form a recording mark in an unrecorded region of the recording layer 14 but also to directly overwrite a recording mark already formed in the recording layer 14 with a new recording mark.

[0035]

In the present invention, as a phase change material for the recording layer 14, a phase change material represented by an atomic

composition formula: $Sb_aTe_bGe_cMn_d$, where the value of *a* is equal to or larger than 57 and equal to or smaller than 74, the value of *c* is equal to or larger than 2 and equal to or smaller than 10, the value of *d* is equal to or larger than 5 and equal to or smaller than 20, the value of $(a + d)$ is equal to or larger than 74 and equal to or smaller than 81 and the value of a/b is equal to or larger than 2.9 and equal to or smaller than 4.7 is used. Here, each of *a*, *b*, *c* and *d* indicates an atomic ratio (%). However, the recording layer 14 may contain elements such as indium (In) other than antimony (Sb), tellurium (Te), germanium (Ge) and manganese (Mn) in an amount equal to or less than 5 atomic %. Thus, in this specification, the statement "a phase change material represented by an atomic composition formula: $Sb_aTe_bGe_cMn_d$" means that the content of elements other than antimony (Sb), tellurium (Te), germanium (Ge) and manganese (Mn) contained in the phase change material is equal to or less than 5 atomic %.

[0036]

In a study done by the inventors of the present invention, it was found that the phase of the phase change material represented by the above atomic composition formula quickly changed from the amorphous phase to the crystal phase, in other words, the phase change material represented by the above atomic composition formula had an extremely high crystallization speed and, therefore, in the case where an optical recording medium 10 included a recording layer 14 containing the phase change material, data recorded in the recording layer 14 of the optical recording medium 10 could be overwritten at an extremely high linear velocity, for example, a linear velocity equal to or higher than 14 m/sec. In a further study done by the inventors of the present invention, it was found that the phase change material had a relatively high

crystallization temperature at which the phase of the phase change material changed from the amorphous phase to the crystal phase and the thermal stability thereof in an amorphous phase was high. It is reasonable to assume that this is mainly because the content of manganese (Mn) contained in the phase change material was increased while the content of antimony (Sb) contained in the phase change material was decreased. Specifically, it can be considered that since the addition of manganese (Mn) tends to increase the crystallization speed and the crystallization temperature of the phase change material, it is possible to simultaneously increase the crystallization speed and the crystallization temperature of the phase change material by replacing a part of antimony (Sb) contained in the phase change material with manganese (Mn). Furthermore, since the phase change material represented by the above atomic composition formula contains germanium (Ge), the crystallization temperature of the phase change material is further increased. Thus, if a recording layer 14 is formed of the phase change material represented by the above atomic composition formula, it is possible to form a recording layer 14 which has improved high-linear-velocity data recording characteristics and is simultaneously improved in data reproduction durability and storage reliability.

[0037]

In a further study done by the inventors of the present invention, it was found that the crystallization temperature of the phase change material increased and the linear velocity at which data could be recorded in the recording layer 14 increased as the content of manganese (Mn) in the phase change material, namely, the value of *d* increased, but that if the crystallization temperature of the phase change material was too high, it was difficult in the case of recording data at a low linear

velocity to form a record mark by changing the phase of the phase change material from the crystalline phase to the amorphous phase. Therefore, it is preferable to adjust the content of manganese (Mn) in the phase change material in accordance with the linear recording velocity of data.

[0038]

Concretely, in the case where a linear recording velocity of data is set to be equal to or higher than 14 m/sec and lower than 21 m/sec, it is preferable for the content of manganese (Mn) in the phase change material, namely, the value of *d*, to be determined equal to or larger than 5 and equal to or smaller than 16. Specifically, in the case where the content of manganese (Mn) in the phase change material, namely, the value of *d* is smaller than 5 at a linear recording velocity equal to or higher than 14 m/sec and lower than 21 m/sec, since the crystallization speed of the phase change material is too low, it becomes difficult to erase a recording mark, namely, crystallize a region of a recording layer 14 where a recording mark is formed and on the other hand, in the case where the content of manganese (Mn) in the phase change material, namely, the value of *d* is larger than 16 at a linear recording velocity equal to or higher than 14 m/sec and lower than 21 m/sec, since the crystallization speed of the phase change material is too high, it becomes difficult to form a recording mark, namely, change the phase of the phase change material to the amorphous phase.

[0039]

Further, in the case where the content of manganese (Mn) in the phase change material, namely, the value of *d*, is determined to be equal to or larger than 5 and equal to or smaller than 16, it is preferable to further determine that the value of *a* is equal to or larger than 58 and equal to or smaller than 74, the value of *c* is equal to or larger than 2 and

equal to or smaller than 10, the value of ($a + d$) is equal to or larger than 74 and equal to or smaller than 79 and the value of a/b is equal to or larger than 2.9 and equal to or smaller than 4.5. In the case where the phase change material contained in the recording layer 14 is determined to have such a composition, when data are to be recorded in the optical recording medium 10 at linear recording velocity equal to or higher than 14 m/sec and lower than 21 m/sec, it is possible to improve the data recording characteristics of an optical recording medium optimally.

[0040]

More specifically, in the case where the content of manganese (Mn) in the phase change material, namely, the value of d, is determined to be equal to or larger than 5 and equal to or smaller than 16, if it is determined that the value of a is smaller than 58, the value of c is larger than 10, the value of ($a + d$) is smaller than 74 or the value of a/b is smaller than 2.9, since the crystallization speed of the phase change material is too low, it becomes difficult to erase a recording mark, namely, crystallize a region of a recording layer 14 where a recording mark is formed and on the other hand, in the case where the content of manganese (Mn) in the phase change material, namely, the value of d, is determined to be equal to or larger than 5 and equal to or smaller than 16, if it is determined that the value of a is larger than 74, the value of ($a + d$) is larger than 79 or the value of a/b is larger than 4.5, since the crystallization speed of the phase change material is too high, it becomes difficult to form a recording mark, namely, change the phase of the phase change material to the amorphous phase.

[0041]

Moreover, in the case where the content of manganese (Mn) in the phase change material, namely, the value of d, is determined to be equal

to or larger than 5 and equal to or smaller than 16, if the value of *c* is smaller than 2, since the crystallization temperature is too low, there arises a risk of data reproduction durability and storage reliability becoming lower.

[0042]

On the other hand, in the case where a linear recording velocity of data is set to be equal to or higher than 21 m/sec and lower than 33 m/sec, it is preferable for the content of manganese (Mn) in the phase change material, namely, the value of *d*, to be determined equal to or larger than 5 and equal to or smaller than 16. Specifically, in the case where the content of manganese (Mn) in the phase change material, namely, the value of *d* is smaller than 11 at a linear recording velocity equal to or higher than 21 m/sec and lower than 33 m/sec, since the crystallization speed of the phase change material is too low, it becomes difficult to erase a recording mark, namely, crystallize a region of a recording layer 14 where a recording mark is formed and on the other hand, in the case where the content of manganese (Mn) in the phase change material, namely, the value of *d* is larger than 20 at a linear recording velocity equal to or higher than 21 m/sec and lower than 33 m/sec, since the crystallization speed of the phase change material is too high, it becomes difficult to form a recording mark, namely, change the phase of the phase change material to the amorphous phase.

[0043]

Further, in the case where the content of manganese (Mn) in the phase change material, namely, the value of *d*, is determined to be equal to or larger than 11and equal to or smaller than 20, it is preferable to further determine that the value of *a* is equal to or larger than 57 and equal to or smaller than 70, the value of *c* is equal to or larger than 2 and

equal to or smaller than 10, the value of ($a + d$) is equal to or larger than 77 and equal to or smaller than 81 and the value of a/b is equal to or larger than 3.3 and equal to or smaller than 4.7. In the case where the phase change material contained in the recording layer 14 is determined to have such a composition, when data are to be recorded in the optical recording medium 10 at linear recording velocity equal to or higher than 21 m/sec and lower than 33 m/sec, it is possible to optimize the data recording characteristics of an optical recording medium.

[0044]

More specifically, in the case where the content of manganese (Mn) in the phase change material, namely, the value of d, is determined to be equal to or larger than 11 and equal to or smaller than 20, if it is determined that the value of a is smaller than 57, the value of c is larger than 10, the value of ($a + d$) is smaller than 77 or the value of a/b is smaller than 3.3, since the crystallization speed of the phase change material is too low, it becomes difficult to erase a recording mark, namely, crystallize a region of a recording layer 14 where a recording mark is formed and on the other hand, in the case where the content of manganese (Mn) in the phase change material, namely, the value of d, is determined to be equal to or larger than 11 and equal to or smaller than 20, if it is determined that the value of a is larger than 70, the value of ($a + d$) is larger than 81 or the value of a/b is larger than 4.7, since the crystallization speed of the phase change material is too high, it becomes difficult to form a recording mark, namely, change the phase of the phase change material to the amorphous phase.

[0045]

Moreover, in the case where the content of manganese (Mn) in the phase change material, namely, the value of d, is determined to be equal

to or larger than 11and equal to or smaller than 20, if the value of *c* is smaller than 2, since the crystallization temperature is too low, there arises a risk of data reproduction durability and storage reliability becoming lower.

[0046]

Thus, it is reasonable to conclude that if the content of manganese (Mn) in the phase change material, namely, the value of *d*, is determined to be equal to or larger than 11and equal to or smaller than 16, data can be recorded in the optical recording medium 10 even if a linear recording velocity is varied over an extremely wide range, namely, at a linear recording velocity equal to or higher than 14 m/sec and equal to or lower than 33 m/sec, for example and that in the case where the content of manganese (Mn) in the phase change material, namely, the value of *d*, is determined to be equal to or larger than 11 and equal to or smaller than 16, it is preferable to determine that the value of *a* is equal to or larger than 60 and equal to or smaller than 70, the value of *c* is equal to or larger than 2 and equal to or smaller than 10, the value of $(a + d)$ is equal to or larger than 77 and equal to or smaller than 79 and the value of a/b is equal to or larger than 3.2 and equal to or smaller than 4.5. In the case where it is determined that the phase change material contained in the recording layer 14 is determined to have such a composition, when data are to be recorded in the optical recording medium 10 by varying over an extremely wide range, namely, at a linear recording velocity equal to or higher than 14 m/sec and equal to or lower than 33 m/sec, it is possible to optimize the data recording characteristics of an optical recording medium.

[0047]

Since the recording sensitivity decreases as the recording layer 14

becomes thicker, it is preferable to form the recording layer 14 to be thin. However, when the recording layer 14 is too thin, the difference in the optical constants between before and after data recording becomes small and a reproduced signal having a high level (C/N ratio) cannot be obtained. Further, when the recording layer 14 is too thin, since the crystallization speed becomes markedly low, it is difficult to directly overwrite data and it is difficult to control the thickness of the recording layer 14 when it is formed. Therefore, the recording layer 14 is preferably formed to have a thickness of 2 to 40 nm, more preferably, to have a thickness of 4 to 30 nm and most preferably to have a thickness of 5 to 20 nm.

[0048]

The first dielectric layer 15 and the second dielectric layer 13 serve to physically and chemically protect the recording layer 14 and it is possible to effectively prevent data recorded in the recording layer 14 from being degraded for a long time by sandwiching the recording layer 14 by the first dielectric layer 15 and the second dielectric layer 13. In addition, the first dielectric layer 15, the second dielectric layer 13 and the heat radiation layer 16 serve to increase the difference in the optical characteristics between before and after data recording and the heat radiation layer 16 further serves to quickly radiate heat generated in the recording layer 14.

[0049]

The material usable for forming the second dielectric layer 13 is not particularly limited insofar as it is transparent with respect to the laser beam L and it is preferable to form the second dielectric layer 13 of a mixture of ZnS and SiO_2. The mole ratio of ZnS to SiO_2 is preferably 40:60 to 60:40 and the mole ratio of ZnS to SiO_2 is most preferably about

50:50, since the mixture of ZnS and SiO_2 whose mole ratio of ZnS to SiO_2 is about 50:50 is chemically stable and has an excellent property for protecting the recording layer 14 when the second dielectric layer 13 is formed thereof.

[0050]

The thickness of the second dielectric layer 13 is not particularly limited but the second dielectric layer 13 is preferably formed to have a thickness of 3 nm to 16 nm. In the case where the thickness of the second dielectric layer 13 is thinner than 3 nm, it becomes difficult to protect the recording layer 14 in a desired manner. Since the thickness of the second dielectric layer 13 greatly influences the heat radiation characteristics of the recording layer 14, it is preferable to determine the thickness of the second dielectric layer 13 depending upon a linear recording velocity at which data are to be recorded in the optical recording medium 10. Specifically, since it is necessary for the recording layer 14 to have higher heat radiation characteristics as a linear recording velocity becomes higher, it is preferable to determine the thickness of the second dielectric layer 13 thicker as a linear recording velocity becomes higher.

[0051]

Concretely, in the case where the linear recording velocity is equal to or higher than 14 m/sec and lower than 21 m/sec, in other words, in the case where the content of manganese (Mn) in the phase change material, namely, the value of *d*, is determined to be equal to or larger than 5 and equal to or smaller than 16, it is preferable to form the second dielectric layer 13 so as to have a thickness of 3 nm to 16 nm, and in the case where a linear recording velocity of data is equal to or higher than 21 m/sec and equal to or lower than 33 m/sec, in other words, in the case where the content of manganese (Mn) in the phase change material,

namely, the value of *d*, is determined to be equal to or larger than 11 and equal to or smaller than 20, it is preferable to form the second dielectric layer 13 so as to have a thickness of 3 nm to 12 nm. If the second dielectric layer 13 is formed in this manner, it is possible to prevent cracks from being generated in the second dielectric layer 13 and optimize the heat radiation characteristics of the recording layer 14 while maintaining the reliability of the optical recording medium 10. Therefore, if the second dielectric layer 13 is formed so as to have a thickness of 3 nm to 12 nm, when data are to be recorded in the optical recording medium 10 by varying over an extremely wide range, namely, at a linear recording velocity equal to or higher than 14 m/sec and equal to or lower than 33 m/sec, it is possible to optimize the data recording characteristics of an optical recording medium.

[0052]

On the other hand, the material for forming the first dielectric layer 15 is not particularly limited but the first dielectric layer 15 is preferably formed of a mixture of ZnS and SiO_2. The mole ratio of ZnS to SiO_2 is preferably 70:30 to 90:10 and more preferably about 80:20. It is possible by forming the first dielectric layer 15 of such a material to improve the characteristics for protecting the recording layer 14 and effectively prevent the recording layer 14 from being deformed by heat generated when data are recorded therein. The thus formed first dielectric layer 15 has an excellent optical characteristic with respect to the laser beam L having a wavelength included in a blue wavelength region. Thus, such a material is suitable for forming a dielectric layer on the side of the light incidence plane 17a with respect to the recording layer 14.

[0053]

Here, it is possible to form an interface layer between the recording layer 14 and the first dielectric layer 15 for preventing the recording layer 14 from being degraded due to repeated recording of data. It is preferable for a dielectric material for forming the interface layer to contain the mixture of ZnS and SiO_2 whose mole ratio is 40:60 to 60:40, particularly, 50:50 as a primary component.

[0054]

The thickness of the first dielectric layer 15 is not particularly limited but the first dielectric layer 15 is preferably formed to have a thickness of 10 nm to 60 nm and more preferably formed to have a thickness of 10 nm to 40 nm. In the case where the thickness of the first dielectric layer 15 is thinner than 10 nm or exceeds 60 nm, it is impossible to sufficiently increase the optical characteristics of the optical recording medium 10 before and after the data recording. In addition, in the case where the thickness of the first dielectric layer 15 is thinner than 10 nm, it becomes difficult to protect the recording layer 14 in a desired manner and on the other hand, in the case where the thickness of the first dielectric layer 15 exceeds 60 nm, the heat radiation effect of the heat radiation layer 16 becomes low. To the contrary, if the first dielectric layer 15 is formed so as to have a thickness of 10 nm to 40 nm, it is possible to obtain the above mentioned effects while the optical characteristics of the optical recording medium and the heat radiation characteristics can be ensured.

[0055]

In the case where an interface layer is interposed between the recording layer 14 and the first dielectric layer 15, it is preferable to form the interface layer so as to have a thickness thinner than that of the first dielectric layer 15. Concretely, in the case where the interface layer is

formed of the mixture of ZnS and SiO_2 whose mole ratio is 50:50 and the first dielectric layer 15 is formed of the mixture of ZnS and SiO_2 whose mole ratio is 80:20, if the thickness of the first dielectric layer 15 is 10 nm to 40 nm, it is preferable to form the interface layer so as to have a thickness of 2 nm to 10 nm. This is because it is sufficient to form the interface layer so as to have a thickness of 2 nm to 10 nm for exhibiting the function thereof and if the interface layer is formed too thick, the first dielectric layer 15 has to be formed thin, whereby there arises a risk of cracks being generated in the optical recording medium 10 due to stress generated in the heat radiation layer 16.

[0056]

The material for forming the heat radiation layer 16 is not particularly limited but the heat radiation layer 16 is preferably formed of the material containing AlN as a primary component. Since AlN has high thermal conductivity, when the heat radiation layer 16 is formed of AlN, it is possible to effectively radiate heat generated in the recording layer 14. Here, in this specification, the statement "the material containing AlN as a primary component" means the material containing 90 atomic % or more of AlN. However, since the heat radiation characteristics of the recording layer 14 can be effectively increased as the amount of AlN contained in the heat radiation layer 16 increases, it is more preferable for the heat radiation layer 16 to contain about 95 atomic % of AlN.

[0057]

The thickness of the heat radiation layer 16 is not particularly limited but it is preferable to form the heat radiation layer 16 to have a thickness of 50 nm to 150 nm and is more preferable to form the heat radiation layer 16 to have a thickness of 80 nm to 120 nm. In the case

where the thickness of the heat radiation layer 16 is thinner than 50 nm, sufficient heat radiation characteristics cannot be obtained and, on the other hand, in the case where the thickness of the heat radiation layer 16 exceeds 150 nm, it takes much time to form the heat radiation layer 16, thereby lowering the productivity of the optical recording medium 10 and giving rise to a risk of cracks being generated in the heat radiation layer 16 due to internal stress. To the contrary, in the case where the heat radiation layer 16 is formed so as to have a thickness of 80 nm to 120 nm, it is possible to improve the heat radiation characteristics of the recording layer 14 while preventing the productivity of the optical recording medium 10 from being lowered and cracks from being generated in the heat radiation layer 16.

[0058]

In the case where the first dielectric layer 15 and the heat radiation layer 16 are integrated and formed of the material containing AlN as a primary component, it is possible to much more effectively radiate heat generated in the recording layer 14. However, in the case where a layer integrated by the first dielectric layer 15 and the heat radiation layer 16 is formed of the material containing AlN as a primary component, since the adhesiveness between itself and the recording layer 14 is low, the data overwriting characteristics are lowered if the layer is brought into direct contact with the recording layer 14, and since the material containing AlN as a primary component has little enhancement effect, sufficient modulation cannot be obtained, whereby the jitter characteristics are lowered. Therefore, in the present invention, the first dielectric layer 15 and the heat radiation layer 16 are separately provided.

[0059]

Each of the reflective layer 12, the second dielectric layer 13, the recording layer 14, the first dielectric layer 15 and the heat radiation layer 16 can be formed using a gas phase growth process using chemical species containing elements for forming it. As the gas phase growth process, a sputtering process is preferably used.

[0060]

The light transmission layer 17 serves to transmit the laser beam L and the light incidence plane 17a is constituted by the surface thereof. It is preferable to form the light transmission layer 17 to have a thickness of 10 μm to 300 μm and is more preferable to form the light transmission layer 17 to have a thickness of 50 μm to 150 μm. The material usable for forming the light transmission layer 17 is not particularly limited insofar as it has a sufficiently high light transmittance with respect to the laser beam L but it is preferable to form the light transmission layer 17 by applying acrylic ultraviolet ray curable resin or epoxy ultraviolet ray curable resin onto the surface of the heat radiation layer 16 using a spin coating process. The light transmission layer 17 may be formed by adhering a sheet made of light transmittable resin to the surface of the heat radiation layer 16 using an adhesive agent.

[0061]

Here, a hard coat layer may be formed on the surface of the light transmission layer 17 to protect the light transmission layer 17. In this case, a light incidence plane is constituted by the surface of the hard coat layer. The material for forming the hard coat layer is not particularly limited insofar as it has higher damage resistance than that of the light transmission layer 17 and is harder than the material for forming the light transmission layer 17. It is possible to form the hard coat layer

using ultraviolet ray curable resin containing epoxy acrylate oligomer (di-functional oligomer), polyfunctional acryl monomer or monofunctional acryl monomer and a photo-polymerization initiator, oxide, nitride, sulfide, carbide of aluminum (Al), silicon (Si), cerium (Ce), titanium (Ti), zinc (Zn), tantalum (Ta) or the like and the mixture thereof, for example. In the case where a hard coat layer is to be formed of ultraviolet ray curable resin, it is preferable to apply ultraviolet ray curable resin onto the light transmission layer 17 to form the hard coat layer and on the other hand, in the case where a hard coat layer is to be formed of the above identified oxide, nitride, sulfide, carbide and the mixture thereof, the hard coat layer can be formed using a gas phase growth process using chemical species containing elements for forming it such as a sputtering process and a vacuum deposition process. Among these, a sputtering process is preferably used.

[0062]

Further, since the hard coat layer serves to prevent the surface of the light transmission layer 17 from being damaged, it is preferable for the hard coat layer not only to be hard but also to have lubricating ability. In order to provide lubricating ability to the hard coat layer, it is effective to add a lubricant to a host material such as SiO_2 of the hard coat layer. It is preferable select a silicone system lubricant, a fluorine system lubricant or a fatty acid ester system lubricant as a lubricant to be added to the host material of the hard coat layer and it is preferable to add such a lubricant to the host material of the hard coat layer in an amount of 0.1 mass % to 5.0 mass %.

[0063]

The above is a layer configuration of the optical recording medium 10 which is a preferred embodiment of the present.

[0064]

In the case where data are to be recording in the optical recording medium 10 having the above described layer configuration, as described above, a laser beam L whose power is modulated is projected onto the optical recording medium 10 from the side of the light incidence plane 17a. When the recording layer 14 is heated to a temperature equal to or higher than the melting point of the phase change material contained in the recording layer 14 to melt the phase change material contained in a region of the recording layer 14 irradiated with the laser beam L and the region where the phase change material is melted is quickly cooled, the phase of the phase change material contained in the region of the recording layer 14 becomes an amorphous phase and on the other hand, when the recording layer 14 is heated to a temperature equal to or higher than the crystallization temperature of the phase change material contained in a region of the recording layer 14 irradiated with the laser beam L and the region of the recording layer 14 is gradually cooled, the phase of the phase change material contained in the region of the recording layer 14 becomes a crystal phase. Since the reflection coefficients of the regions of the recording layer 14 are different between the region the recording layer 14 where the phase change material is in an amorphous phase and the region thereof where the phase change material is in a crystal phase and which corresponds to a blank region, data can be reproduced utilizing these characteristics of the phase change material.

[0065]

Next, an optical data recording method which is a preferred embodiment of the present invention will be described below.

[0066]

Figure 2 is a diagram showing the waveform of a pulse train pattern employed for modulating the power of a laser beam L when data are to be recorded in the optical recording medium 10, where Figure 2 (a) shows a pulse train pattern used in the case of recording a 2T signal or a 3T signal, Figure 2 (b) shows a pulse train pattern used in the case of recording a 4T signal or a 5T signal, Figure 2 (c) shows a pulse train pattern used in the case of recording a 6T signal or a 7T signal and Figure 2 (d) shows a pulse train pattern used in the case of recording an 8T signal.

[0067]

As shown in Figures 2 (a) to 2 (d), in the optical data recording method according to this embodiment, the power of a laser beam L is modulated between three levels (three values), namely, a recording power *Pw*, an erasing power *Pe* and a bottom power *Pb* and in this embodiment, the recording power *Pw* is set to be higher than the erasing power *Pe* and the erasing power *Pe* is set to be higher than the bottom power *Pb*. The recording power *Pw* is set to such a high level that the phase change material contained in the recording layer 14 is heated to a temperature higher than the melting point thereof when the laser beam L whose power is set to the recording power *Pw* is projected onto the recording layer 14 and on the other hand, the erasing power *Pe* is set to such a level that the phase change material contained in the recording layer 14 is heated to a temperature equal to or higher than the crystallization temperature thereof when the laser beam L whose power is set to the erasing power *Pe* is projected onto the recording layer 14. To the contrary, the bottom power *Pb* is set to such a low level that regions of the recording layer 14 heated by irradiation with the laser beam L whose power is set to the recording power *Pw* can be cooled by irradiation with

the laser beam L whose power is set to the bottom power *Pb*.

[0068]

It is preferable to set a ratio *Pe/Pw* of the erasing power *Pe* to the recording power *Pw* to be equal to or larger than 0.26 and equal to or smaller than 0.51. Since the ratio *Pe/Pw* of the erasing power *Pe* to the recording power *Pw* greatly influences the data direct overwriting characteristics of the optical recording medium 10, it is preferable to determine it depending upon the linear recording velocity of data. More specifically, since it is necessary to set the recording power *Pw* to be higher as the linear recording velocity of data is higher, it is preferable to set the ratio *Pe/Pw* of the erasing power *Pe* to the recording power *Pw* smaller as the linear recording velocity of data is higher.

[0069]

Concretely, in the case where the linear recording velocity of data is equal to or higher than 14 m/sec and lower than 21 m/sec, it is preferable to set the ratio *Pe/Pw* of the erasing power *Pe* to the recording power *Pw* to be equal to or larger than 0.27 and equal to or smaller than 0.51, and in the case where the linear recording velocity of data is equal to or higher than 21 m/sec and equal to or lower than 33 m/sec, it is preferable to set the ratio *Pe/Pw* of the erasing power *Pe* to the recording power *Pw* to be equal to or larger than 0.26 and equal to or smaller than 0.47. In a study done by the inventors of the present invention, it was found that in the case where the ratio *Pe/Pw* of the erasing power *Pe* to the recording power *Pw* was set in this manner, it was possible not only to form a record mark having a good shape but also to erase a record mark efficiently, thereby ensuring good data direct overwriting characteristics.

[0070]

Therefore, in the case where the ratio *Pe*/*Pw* of the erasing power *Pe* to the recording power *Pw* is set to be equal to or larger than 0.27 and equal to or smaller than 0.47, it is possible to improve the data recording characteristics of an optical recording medium within the wide range of a linear recording velocity of 14 m/sec to 33 m/sec.

[0071]

In the optical data recording method according to this embodiment, in the case where a recording mark having a length corresponding to nT where T is a length corresponding to one cycle of a reference clock cycle is to be formed, the number of recording pulses is determined to be $n/2$ when n is an even number and the number of recording pulses is determined to be $(n - 1)/2$ when n is an odd number. Here, the terms "the number of recording pulses" are defined as the number of pulses having a level equal to the recording power *Pw*. Next, concrete pulse trains will be described in detail below.

[0072]

As shown in Figure 2 (a), in the case of recording a 2T signal or a 3T signal in the recording layer 14 of the optical recording medium 10, the number of recording pulses included in the pulse train pattern used for modulating the power of a laser beam L is set to "1" and a cooling time period t_{cl} is inserted into the pulse train pattern after the recording pulses. As described above, the terms "the number of recording pulses" are defined as the number of pulses having a level equal to the recording power *Pw*. A recording pulse located at a leading position among the recording pulses included in the pulse train pattern used for modulating the power of a laser beam L is referred to as a top pulse, a recording pulse located in a last position among the recording pulses is referred to as a last pulse and a recording pulse(s) located between the top pulse and

the last pulse is referred to as a multipulse. In this connection, as shown in Figure 2 (a), in the case where the number of recording pulses is "1", the recording pulse corresponds to a top pulse.

[0073]

In the cooling time period t_{cl}, the level of the power of a laser beam L is set to the bottom power *Pb*. In this specification, a last time period of the pulse train pattern in which the level of the power of a laser beam L is set to the bottom power *Pb* is referred to as "the cooling time period" and a time period between the top pulse and the cooling time period is referred to as "a heating time period". In the case of recording a 2T signal or a 3T signal in the recording layer 14 of the optical recording medium 10, the power of the laser beam L is modulated so that it is increased from the erasing power *Pe* to the recording power *Pw* at a time t11, decreased from the recording power *Pw* to the bottom power *Pb* at a time t12 after passage of a predetermined time period t_{top} corresponding to a top pulse, and increased from the bottom power *Pb* to the erasing power *Pe* at a time t13 after passage of a predetermined cooling time period t_{cl}. Therefore, in the case of recording a 2T signal or a 3T signal in the recording layer 14 of the optical recording medium 10, a time period from the time t11 to the time t12 corresponds to a heating time period and a time period from the time t12 to the time t13 corresponds to a cooling time period.

[0074]

Further, as shown in Figure 2 (b), in the case of recording a 4T signal or a 5T signal in the recording layer 14 of the optical recording medium 10, the number of recording pulses is set to "2" and a cooling time period t_{cl} is inserted into the pulse train pattern after the recording pulses. More specifically, in the case of recording a 4T signal or a 5T

signal in the recording layer 14 of the optical recording medium 10, the power of the laser beam L is modulated so that it is kept to be the erasing power *Pe* before a time t21, is equal to the recording power *Pw* during a predetermined time period t_{top} corresponding to a top pulse between the time t21 and a time t22 and during a predetermined time period t_{lp} corresponding to a last pulse between a time t23 and a time t24, is equal to the bottom power *Pb* during a predetermined off time period t_{off} between the time t22 and the time t23 and during a predetermined cooling time period t_{cl} between the time t24 and a time t25 and is equal to the erasing power *Pe* after the time t25. Therefore, in the case of recording a 4T signal or a 5T signal in the recording layer 14 of the optical recording medium 10, a time period from the time t21 to the t24 corresponds to a heating time period and a time period from the time t24 to the time t25 corresponds to a cooling time period.

[0075]

Furthermore, as shown in Figure 2 (c), in the case of recording a 6T signal or a 7T signal in the recording layer 14 of the optical recording medium 10, the number of recording pulses is set to "3" and a cooling time period t_{cl} is inserted into the pulse train pattern after the recording pulses. More specifically, in the case of recording a 6T signal or a 7T signal in the recording layer 14 of the optical recording medium 10, the power of the laser beam L is modulated so that it is kept to the erasing power *Pe* before a time t31, is equal to the recording power *Pw* during a predetermined time period t_{top} corresponding to a top pulse between the time t31 and a time t32, during a predetermined time period t_{mp} corresponding to a multipulse between a time t33 and a time t34 and during a predetermined time period t_{lp} corresponding to a last pulse between a time t35 and a time t36, is equal to the bottom power *Pb*

during a predetermined off time period t_{off} between the time t32 and the time t33, during a predetermined off time period t_{off} between the time t34 and the time t35 and during a predetermined cooling time period t_{cl} between the time t36 and a time t37 and is equal to the erasing power *Pe* after the time t37. Therefore, in the case of recording a 6T signal or a 7T signal in the recording layer 14 of the optical recording medium 10, a time period from the time t31 to the t36 corresponds to a heating time period and a time period from the time t36 to the time t37 corresponds to a cooling time period.

[0076]

Moreover, as shown in Figure 2 (d), in the case of recording an 8T signal in the recording layer 14 of the optical recording medium 10, the number of recording pulses is set to "4" and a cooling time period t_{cl} is inserted into the pulse train pattern after the recording pulses. More specifically, in the case of recording an 8T signal in the recording layer 14 of the optical recording medium 10, the power of the laser beam L is modulated so that it is kept to the erasing power *Pe* before a time t41, is equal to the recording power *Pw* during a predetermined time period t_{top} corresponding to a top pulse between the time t41 and a time t42, during a predetermined time period t_{mp} corresponding to a multipulse between a time t43 and a time t44, during a predetermined time period t_{mp} corresponding to a multipulse between a time t45 and a time t46 and during a predetermined time period t_{lp} corresponding to a last pulse between a time t47 and a time t48, is equal to the bottom power *Pb* during a predetermined off time period t_{off} between the time t42 and the time t43, during a predetermined off time period t_{off} between the time t44 and the time t45, during a predetermined off time period t_{off} between the time t46 and the time t47 and during a predetermined cooling time

period t_{cl} between the time t48 and a time t49 and is equal to the erasing power *Pe* after the time t49. Therefore, in the case of recording an 8T signal in the recording layer 14 of the optical recording medium 10, a time period from the time t41 to the t48 corresponds to a heating time period and a time period from the time t48 to the time t49 corresponds to a cooling time period.

[0077]

Thus, in a region of the recording layer 14 where one of a 2T signal to an 8T signal is to be recorded, since the phase change material contained therein is heated to a temperature equal to or higher than the melting point thereof during the heating time period and then quickly cooled during the cooling time period, the phase of the phase change material is kept in an amorphous phase. On the other hand, in a region where a blank region is to be formed, namely, a region between neighboring recording marks, the phase change material contained therein is heated to a temperature equal to or higher than the crystallization temperature thereof by the irradiation with a laser beam whose power is fixed to the erasing power *Pe* and gradually cooled by moving the laser beam L away therefrom, the phase of the phase change material is kept in or changed to a crystal phase. Therefore, it is possible not only to newly record data in an unrecorded region of the recording layer 14 but also to directly over write a recording mark formed in the recording layer 14 with a new recording mark.

[0078]

As described above, in this preferred embodiment, since in the case where a recording mark having a length corresponding to nT where T is a length corresponding to one cycle of a reference clock cycle is to be formed, the number of recording pulses is determined to be $n/2$ when n is

an even number, in other words, when a recording mark having a length corresponding to one of a 2T signal, 4T signal, 6T signal and an 8T signal is to be formed and the number of recording pulses is determined to be $(n - 1)/2$ when n is an odd number, in other words, when a recording mark having a length corresponding to one of a 3T signal, a 5T signal and a 7T signal is to be formed, the number of recording pulses for forming one recording mark is less than that used in a conventional divided pulse modulating method. Therefore, since the width of each of recording pulses, namely, a time period t_{top} corresponding to a top pulse, a time period t_{mp} corresponding to a multipulse and a time period t_{lp} corresponding to a last pulse and an interval between neighboring recording pulses, namely, an off time period t_{off} become longer than those used in a conventional divided pulse modulating method, it possible to accurately control the temperature of the recording layer 14 even if data are to be recorded in the recording layer at an extremely high linear recording velocity. Thus, even in the case where data are to be recorded in the recording layer at an extremely high linear recording velocity, it is possible to form a recording mark having a desired shape.

[0079]

On the other hand, the maximum speed for modulating the power of a laser beam L is restricted by the ability of a laser driver for driving a semiconductor laser source. Therefore, in the case where data are to be recorded in an optical recording medium at an extremely high linear recording velocity by modulating the power of a laser beam L using a conventional divided pulse modulating method, the power of a laser beam do not sometimes reach the recording power *Pw*. For example, in the case where data are to be recorded in an optical recording medium at a linear recording velocity Of 14 m/sec by a conventional divided pulse

modulating method using $(n - 1)$ recording pulses, since the shortest width of a recording pulse becomes about 1.7 nsec, even if a high speed laser driver is employed for modulating the power of a laser beam, it is impossible to modulate the power of the laser beam. To the contrary, in the case where data are to be recorded in accordance with this preferred embodiment of the present invention, since the shortest width of a recording pulse becomes about 4.0 nsec, if a high speed laser driver is employed for modulating the power of a laser beam, it is possible to modulate the power of the laser beam in a desired manner.

[0080]

The above is the optical recording method according to the preferred embodiment of the present invention.

[0081]

It is preferable to store information for identifying the above described pulse train patterns according to the preferred embodiment of the present invention in the optical recording medium 10 as "recording condition setting information". In the case where such recording condition setting information is stored in the optical recording medium 10, when data are to be recorded by a user, the recording condition setting information is read by a data optical recording apparatus, whereby a pulse pattern can be determined based on the thus read recording condition setting information.

[0082]

Here, it is preferable for the recording condition setting information to include not only information necessary for determining pulse train patterns but also information necessary for determining various recording conditions such as a linear recording velocity required for recording data in the optical recording medium 10. For example, in

the case where the content *d* of manganese (Mn) contained in the recording layer 14 of the optical recording medium 10 is equal to or larger than 5 and equal to or smaller than 16 and the composition of the recording layer 14 is optimized for recording data at a linear recording velocity equal to or higher than 14 m/sec and lower than 21 m/sec, it is preferable for the recording condition setting information to include information that a linear recording velocity should be determined to be equal to or higher than 14 m/sec and lower than 21 m/sec and on the other hand, in the case where the content *d* of manganese (Mn) contained in the recording layer 14 of the optical recording medium 10 is equal to or larger than 11 and equal to or smaller than 20 and the composition of the recording layer 14 is optimized for recording data at a linear recording velocity equal to or higher than 21 m/sec and equal to or lower than 33 m/sec, it is preferable for the recording condition setting information to include information that a linear recording velocity should be determined to be equal to or higher than 21 m/sec and equal to or lower than 33 m/sec. Moreover, in the case where the content *d* of manganese (Mn) contained in the recording layer 14 of the optical recording medium 10 is equal to or larger than 11 and equal to or smaller than 16 and the composition of the recording layer 14 is optimized for recording data at a linear recording velocity equal to or higher than 14 m/sec and equal to or lower than 33 m/sec, it is preferable for the recording condition setting information to include information that a linear recording velocity should be determined to be equal to or higher than 14 m/sec and equal to or lower than 33 m/sec.

[0083]

The recording condition setting information may be stored in the optical recording medium 10 in the form of wobbles or pre-pits or may be

recorded as data in the recording layer 14. It is not absolutely necessary for the recording condition setting information to be constituted so as to directly indicate conditions necessary for recording data but may be constituted so as to specify one of conditions stored in a data optical recording apparatus in advance, thereby indirectly identifying recording conditions such as a pulse pattern.

[0084]

Next, a data optical recording apparatus for recording data in the optical recording medium 10 will be described below.

[0085]

Figure 3 is a diagram showing a data optical recording apparatus 100 for recording data in the optical recording medium 10.

[0086]

As shown in Figure 3, a data optical recording apparatus 100 includes a spindle motor 101 for rotating the optical recording medium 10, an optical head 110 for projecting a laser beam L onto the optical recording medium 10 and receiving the laser beam L' reflected by the optical recording medium 10, a traverse motor 102 for moving the optical head 110 in a radial direction of the optical recording medium 10, a laser drive circuit 103 for feeding a laser drive signal 103a to the optical head 110, a lens drive circuit 104 for feeding a lens drive signal 104a to the optical head 110, and a controller 105 for controlling the spindle motor 101, the traverse motor 102, the laser drive circuit 103 and the lens drive circuit 104.

[0087]

The optical head 110 includes a laser beam source 111 for emitting the laser beam L based on the laser drive signal 103a, a collimator lens 112 for making the laser beam L emitted from the laser beam source 111

a parallel beam, a beam splitter 113 disposed in the optical path of the laser beam L, an objective lens 105 for condensing the laser beam L, an actuator 106 for moving the objective lens 105 in the vertical direction and the horizontal direction based on the lens drive signal 104a, and a photodetector 116 for receiving the laser beam L' reflected by the optical recording medium 10 and photoelectrically converting it.

[0088]

The spindle motor 101 is controlled by the controller 105 so as to rotate the optical recording medium 10 at a desired speed of rotation. The methods for controlling the rotation of the optical recording medium 10 are roughly classified into the CLV method of rotating the optical recording medium 10 while keeping the linear velocity constant and the CAV method of rotating the optical recording medium 10 while keeping the angular velocity constant. In the case where the rotation of the optical recording medium 10 is controlled using the CLV method, since the data transfer rate can be kept constant irrespective of the position in the radial direction of the optical recording medium 10 where data are being recorded or data are being reproduced, data can be recorded in or data can be reproduced from the optical recording medium 10 at a high transfer rate at all times, so that data can be recorded at high density. To the contrary, however, since the speed of rotation of the optical recording medium 10 has to be changed in accordance with the position in the radial direction of the optical recording medium 10 where data are being recorded or data are being reproduced, it is necessary to control the spindle motor 101 in a complicated manner and, therefore, the random access speed is low. On the other hand, in the case where the rotation of the optical recording medium 10 is controlled using the CAV method, since the spindle motor 101 can be controlled in a simple manner, the

random access speed is high. On the other hand, however, the CAV method is disadvantageous in that the data recording density at the outer circumference portion of the optical recording medium 10 becomes slightly lower. Thus, the CLV method is employed in most of systems for recording data in or reproducing data from an optical recording medium which are put to practical use, since data can be recorded in an optical recording medium at high density and a data transfer rate can be utilized to the maximum extent possible.

[0089]

The traverse motor 102 is controlled by the controller 105 so as to move the optical head 110 in the radial direction of the optical recording medium 10 and when data are to be recorded in the optical recording medium 10 or data are to be reproduced from the optical recording medium 10, it moves the optical head 110 so that the spot of the laser beam L gradually moves along the groove 11b spirally formed on the optical recording medium 10 from the inner circumference portion to the outer circumference portion of the optical recording medium 10. In the case of changing the position in the radial direction of the optical recording medium 10 where data are to be recorded or data are to be reproduced, the controller 105 controls the traverse motor 102 to move the spot of the laser beam L to the desired position on the optical recording medium 10.

[0090]

The laser drive circuit 103 is controlled by the controller 105 so as to feed a laser drive signal 103a to the laser beam source 111 of the optical head 110. The laser beam source 111 generates a laser beam L whose power corresponds to the laser drive signal 103a fed from the laser drive circuit 103. When data are to be recorded in the optical recording

medium 10, the laser drive circuit 103 generates a laser drive signal 103a whose intensity is modulated so that the power of the laser beam L can be modulated in accordance with the above described pulse pattern and feeds it to the laser beam source 111 of the optical head 110. On the other hand, when data are to be reproduced from the optical recording medium 10, the laser drive circuit 103 generates a laser drive signal having a constant intensity and feeds it to the laser beam source 111 of the optical head 110, thereby causing the laser beam source 111 to emit a laser beam L having a reproduction power *Pr* of a constant level.

[0091]

The lens drive circuit 104 is controlled by the controller 105 so as to feed a lens drive signal to the actuator 115, whereby the spot of the laser beam L can be correctly focused on the recording layer 14 of the optical recording medium 10 and follow the groove 11b of the optical recording medium 10. Specifically, the controller 105 is provided with a focus control circuit 105a and when the focus control circuit 105a is turned on, the spot of the laser beam L is focused on the recording layer 14 of the optical recording medium 10 and fixed thereon. The controller is further provided with a tracking control circuit 105b and when the tracking control circuit 105b is turned on, the spot of the laser beam L automatically follows the groove 11b of the optical recording medium 10.

[0092]

In the case where a laser beam L is to be projected onto the optical recording medium 10 using the thus constituted data optical recording apparatus, the controller 105 controls the laser drive circuit 103 to cause it to generate and feed a laser drive signal 103a to the laser beam source 111 of the optical head 110. When the laser beam source 111 receives the laser drive signal 103a, it generates a laser beam L and the laser beam L

enters the collimator lens 112 to be made a parallel beam. The laser beam L then enters the objective lens 114 via the beam splitter 113 and is converged onto the groove 11b formed on the optical recording medium 10.

[0093]

On the other hand, the laser beam L' reflected by the recording layer 14 of the optical recording medium 10 is made a parallel beam by the objective lens 114 and reflected by the beam splitter 113. The laser beam L' reflected by the beam splitter 113 impinges on the photodetector 116 to be photoelectrically detected thereby and the thus produced data are output to the controller 105.

[0094]

In the case where data are to be recorded in an optical recording medium 10 using the thus constituted data optical recording apparatus 100, the controller 105 reads the recording condition setting information recorded in the optical recording medium 10 and controls data recording operation based on the thus read recording condition setting information. Specifically, the controller 105 controls the laser drive circuit 103 so as to obtain a waveform of a laser beam L in accordance with the above described pulse train patterns.

[0095]

In this manner, since data are recorded in an optical recording medium 10 by a laser beam L whose power is modulated in accordance with the pulse train patterns shown in Figure 2 based on the recording condition setting information recorded in the optical recording medium 10, even in the case where data are to be recorded in an optical recording medium 10 at an extremely high linear recording velocity such as 14 m/sec, it is possible to provide an optical recording medium whose

characteristics of recording data therein at a high linear velocity can be improved.

[0096]

The present invention has thus been shown and described with reference to a specific embodiment. However, it should be noted that the present invention is in no way limited to the details of the described arrangements but changes and modifications may be made without departing from the scope of the appended claims.

[0097]

For example, in the above described preferred embodiment, although in the case where a recording mark having a length corresponding to nT is to be formed in the recording layer 14 of the optical recording medium 10, the number of recording pulses is determined to be $(n-1)/2$ when n is an odd number, in other words, when a recording mark having a length corresponding to one of a 3T signal, a 5T signal and a 7T signal is to be formed, it is possible for the number of recording pulses to be determined to be $(n+1)/2$. In such a case, when a recording mark having a length corresponding to a 2T signal, a 3T signal, a 4T signal, a 5T signal, a 6T signal, a 7T signal, or an 8T signal is to be formed in the recording layer 14 of the optical recording medium 10, the number of recording pulses is determined to be 1, 2, 2, 3, 3, 4 or 4.

[0098]

[WORKING EXAMPLE]

Hereinafter, a working example will be set out in order to further describe the present invention concretely. However, the present invention is in no way limited to the working example.

[0099]

[Fabrication an optical recording medium sample]

An optical recording medium sample having the same configuration as that of the optical recording medium 1 shown in Figure 1 was fabricated in the following manner.

[0100]

A support substrate 11 of polycarbonate having a thickness of 1.1 mm and a diameter of 120 mm and formed with grooves 11a and lands 11b on the surface thereof was first fabricated by an injection molding process.

[0101]

Then, the support substrate 11 was set on a sputtering apparatus and a reflective layer 12 consisting of an alloy (APC alloy) containing silver (Ag) as a primary component and added with palladium (Pd) and copper (Cu) and having a thickness of about 100 nm, a dielectric layer 13 consisting of a mixture of ZnS and SiO_2 whose mole ratio was about 50:50 and having a thickness of about 10 nm, a recording layer 14 consisting of $Sb_aTe_bGe_cMn_d$ where the value of *a* was determined to be equal to 63.9, the value of *b* was determined to be equal to 15.2, the value of *c* was determined to be equal to 6.2 and the value of *d* was determined to be equal to 14.7 and having a thickness of about 12 nm, a dielectric layer 15 consisting of the mixture of ZnS and SiO_2 whose mole ratio was about 50:50 and having a thickness of about 25 nm and a heat radiation layer consisting of AlN and having a thickness of about 100 nm were sequentially formed on the surface of the substrate on which the grooves and lands were formed, using the sputtering process.

[0102]

Further, the heat radiation layer was coated with an acrylic system ultraviolet curable resin to form a coating layer and the coating

layer was irradiated with ultraviolet rays, thereby curing the acrylic system ultraviolet curing resin to form a protective layer having a thickness of 100 μm. Thus, the optical recording medium sample of Working Example 1 was fabricated.

[0103]

Furthermore, an optical recording medium sample of Working Example 2-1 was fabricated in the manner of the optical recording medium sample of Working Example 1 except that a recording layer 14 consisting of $Sb_aTe_bGe_cMn_d$ was formed where the value of *a* was determined to be equal to 69.5, the value of *b* was determined to be equal to 16.5, the value of *c* was determined to be equal to 5.7 and the value of *d* was determined to be equal to 8.3.

[0104]

Further, an optical recording medium sample of Working Example 2-2 was fabricated in the manner of the optical recording medium sample of Working Example 1 except that a recording layer 14 consisting of $Sb_aTe_bGe_cMn_d$ was formed where the value of *a* was determined to be equal to 65.0, the value of *b* was determined to be equal to 18.3, the value of *c* was determined to be equal to 5.2 and the value of *d* was determined to be equal to 11.5.

[0105]

Moreover, an optical recording medium sample of Working Example 2-3 was fabricated in the manner of the optical recording medium sample of Working Example 1 except that a recording layer 14 consisting of $Sb_aTe_bGe_cMn_d$ was formed where the value of *a* was determined to be equal to 62.5, the value of *b* was determined to be equal to 20.8, the value of *c* was determined to be equal to 3.6 and the value of *d* was determined to be equal to 13.1.

[0106]

Further, an optical recording medium sample of Working Example 2-4 was fabricated in the manner of the optical recording medium sample of Working Example 1 except that a dielectric layer 13 was formed so as to have a thickness of about 14 nm.

[0107]

Furthermore, an optical recording medium sample of Working Example 2-5 was fabricated in the manner of the optical recording medium sample of Working Example 1 except that a recording layer 14 consisting of $Sb_aTe_bGe_cMn_d$ was formed where the value of *a* was determined to be equal to 72.1, the value of *b* was determined to be equal to 17.2, the value of *c* was determined to be equal to 5.5 and the value of *d* was determined to be equal to 5.2.

[0108]

Moreover, an optical recording medium sample of Working Example 3-1 was fabricated in the manner of the optical recording medium sample of Working Example 1 except that a recording layer 14 consisting of $Sb_aTe_bGe_cMn_d$ was formed where the value of *a* was determined to be equal to 60.8, the value of *b* was determined to be equal to 14.4, the value of *c* was determined to be equal to 6.1 and the value of *d* was determined to be equal to 18.7.

[0109]

Further, an optical recording medium sample of Working Example 3-2 was fabricated in the manner of the optical recording medium sample of Working Example 1 except that a recording layer 14 consisting of $Sb_aTe_bGe_cMn_d$ was formed where the value of *a* was determined to be equal to 64.6, the value of *b* was determined to be equal to 14.0, the value of *c* was determined to be equal to 6.2 and the value of *d* was determined

to be equal to 15.2.

[0110]

Furthermore, an optical recording medium sample of Working Example 3-3 was fabricated in the manner of the optical recording medium sample of Working Example 1 except that a recording layer 14 consisting of $Sb_aTe_bGe_cMn_d$ was formed where the value of *a* was determined to be equal to 59.2, the value of *b* was determined to be equal to 14.1, the value of *c* was determined to be equal to 7.1 and the value of *d* was determined to be equal to 19.6.

[0111]

Moreover, an optical recording medium sample of Comparison Example 1 was fabricated in the manner of the optical recording medium sample of Working Example 1 except that a recording layer 14 consisting of $Sb_aTe_bGe_cMn_d$ was formed where the value of *a* was determined to be equal to 63.8, the value of *b* was determined to be equal to 21.3, the value of *c* was determined to be equal to 5.1 and the value of *d* was determined to be equal to 9.8.

[0112]

Further, an optical recording medium sample of Comparison Example 2 was fabricated in the manner of the optical recording medium sample of Working Example 1 except that a recording layer 14 consisting of $Sb_aTe_bGe_cMn_d$ was formed where the value of *a* was determined to be equal to 75.7, the value of *b* was determined to be equal to 18.0, the value of *c* was determined to be equal to 4.1 and the value of *d* was determined to be equal to 2.2.

[0113]

Furthermore, an optical recording medium sample of Comparison Example 3 was fabricated in the manner of the optical recording medium

sample of Working Example 1 except that a dielectric layer 13 was formed so as to have a thickness of about 18 nm.

[0114]

The compositions of the recording layers and thicknesses of the dielectric layers 13 according to these Working Examples and Comparison Examples are shown in Table 1.

[0115]

[Table 1]

	Thickness of Dielectric Layer 13	Composition of Recording Layer 14					Ratio of Sb/Te
		Sb	Te	Ge	Mn	Sb+ Mn	
Working Example 1	10nm	63.9	15.2	6.2	14.7	78.6	4.2
Working Example 2-1	10nm	69.5	16.5	5.7	8.3	77.8	4.2
Working Example 2-2	10nm	65.0	18.3	5.2	11.5	76.5	3.6
Working Example 2-3	10nm	62.5	20.8	3.6	13.1	75.6	3.0
Working Example 2-4	14nm	63.9	15.2	6.2	14.7	78.6	4.2
Working Example 2-5	10nm	72.1	17.2	5.5	5.2	77.3	4.2
Working Example 3-1	10nm	60.8	14.4	6.1	18.7	79.5	4.2
Working Example 3-2	10nm	64.6	14	6.2	15.2	79.8	4.6
Working Example 3-3	10nm	59.2	14.1	7.1	19.6	78.8	4.2
Comparative Example 1	10nm	63.8	21.3	5.1	9.8	73.6	3.0
Comparative Example 2	10nm	75.7	18.0	4.1	2.2	77.9	4.2
Comparative Example 3	18nm	63.9	15.2	6.2	14.7	78.6	4.2

[0116]

As shown in Table 1, the optical recording medium sample of Working Example 1 is optimized to be recorded with data at a linear recording velocity equal to or higher than 14 m/sec and equal to or lower than 33 m/sec and the optical recording medium samples of Working Example 2-1 to 2-5 are optimized to be recorded with data at a linear recording velocity equal to or higher than 14 m/sec and lower than 21 m/sec. Further, the optical recording medium samples of Working Example 3-1 to 3-3 are optimized to be recorded with data at a linear recording velocity equal to or higher than 21 m/sec and equal to or lower than 33 m/sec.

[0117]

[Evaluation 1 of Characteristics of Optical Recording Medium Samples]

Data were recorded in each of the optical recording medium samples at a linear recording velocity of 15.9 m/sec and jitter of a reproduced signal, a data erasing efficiency and a storage reliability of each sample were evaluated.

[0118]

More specifically, each of the optical recording medium samples was set in an optical recording medium evaluation apparatus "DDU1000" (Product Name) manufactured by Pulstec Industrial Co., Ltd. and a laser beam having a wavelength λ of 405 nm was focused onto each of the recording layers 14 using an objective lens whose numerical aperture was 0.85 via the light incidence plane 17a while each sample was rotated at a linear velocity of 15.9 m/sec, thereby recording random signals including 2T signals to 8T signals in the 1,7 RLL Modulation Code therein. The power of the laser beam was modulated in accordance with the pulse train patterns shown in Figure 2 wherein the recording power

Pw of the laser beam was set to be 8.5 mW, the erasing power *Pe* of the laser beam was set to be 3.5 mW and the bottom power *Pb* of the laser beam was set to be 0.3 mW. Therefore, *Pe* / *Pw* of the erasing power *Pe* to the recording power *Pw* was 0.4.

[0119]

Then, the random signal recorded in each of the optical recording medium samples was reproduced and jitter of the reproduced signal was measured. Here, jitter indicated clock jitter and the fluctuation σ of a reproduced signal was measured using a time interval analyzer and the clock jitter was calculated as σ/Tw, where Tw was one clock period.

[0120]

Further, an 8T single signal was recorded in a track of the recording layer of each of the optical recording medium samples other than the track in which the random signals were recorded in a manner similar to that of recording the random signals in each sample. Then, the 8T signal recorded in the recording layer of each of the optical recording medium samples was reproduced and the carrier level C1 of the reproduced signal was measured. Further, a direct current laser beam was projected onto the track of the recording layer of each of the optical recording medium samples in which the 8T single signal was recorded, thereby recording a signal therein and the recorded signal was reproduced to measure the carrier level C2 of the reproduced signal. The power of the direct current laser beam was set to the erasing power *Pe*. Then, a data erasing efficiency defined by (C1 – C2) was calculated.

[0121]

Furthermore, each of the optical recording medium samples was stored under a temperature of 80 °C for 50 hours, thereby performing a storage test. Then, the random signals recorded in each sample prior to

the storage test were reproduced and clock jitter of a reproduced signal was measured.

[0122]

In this manner, data were recorded in each of the optical recording medium samples at a linear recording velocity of 15.9 m/sec and jitter of a reproduced signal, a data erasing efficiency and a storage reliability of each sample were evaluated. Clock jitter of the signals obtained by reproducing the random signals recorded in each sample was rated GOOD (O) when it was equal to or lower than 10 %, the data erasing efficiency of each sample was rated as GOOD (O) when it was equal to or higher than 25 dB and the storage reliability of each sample was rated GOOD (O) when the increase in clock jitter between before and after the storage test was equal to or smaller than 1 %.

[0123]

[Table 2]

	Jitter	Data Erasing Efficiency	Storage Reliability
Working Example 1	○	○	○
Working Example 2-1	○	○	○
Working Example 2-2	○	○	○
Working Example 2-3	○	○	○
Working Example 2-4	○	○	○
Working Example 2-5	○	○	○
Working Example 3-1	×	○	×
Working Example 3-2	×	○	×
Working Example 3-3	×	○	×
Comparative Example 1	×	×	×
Comparative Example 2	×	×	×
Comparative Example 3	×	○	×

[0124]

As shown in Table 2, it was found that clock jitter, the data erasing efficiency and the storage reliability were good in each of the optical recording medium samples of Working Example 1 and Working Examples 2-1 to 2-5 and it was confirmed that each of the optical recording medium samples of Working Example 1 and Working Examples 2-1 to 2-5 exhibited good recording characteristics when data were recorded therein at a linear recording velocity of 15.9 m/sec.

[0125]

[Evaluation 2 of Characteristics of Optical Recording Medium Samples]

Further, data were recorded in each of the optical recording medium samples at a linear recording velocity of 31.8 m/sec and similarly to Evaluation 1 of Characteristics of Optical Recording Medium Samples, jitter of a signal reproduced from each of the optical recording medium samples, a data erasing efficiency and a storage reliability of each of the optical recording medium samples were evaluated. The evaluation was effected in the manner of Evaluation 1 of Characteristics of Optical Recording Medium Samples except that the recording power Pw of the laser beam was set to be 10.5 mW, the erasing power Pe of the laser beam was set to be 3.0 mW and the bottom power Pb of the laser beam was set to be 0.3 mW. Therefore, the ratio Pe / Pw of the erasing power Pe to the recording power Pw was 0.29. Clock jitter of the signals obtained by reproducing the random signals recorded in each sample was rated GOOD (O) when it was equal to or lower than 10 %, the data erasing efficiency of each sample was rated as GOOD (O) when it was equal to or higher than 25 dB and the storage reliability of each sample was rated GOOD (O) when the increase in clock jitter between before and after the storage test was equal to or smaller than 1 %.

[0126]

The results of the evaluation are shown in Table 3.

[0127]

[Table 3]

	Jitter	Data Erasing Efficiency	Storage Reliability
Working Example 1	○	○	○
Working Example 2-1	×	×	×
Working Example 2-2	×	×	×
Working Example 2-3	×	×	×
Working Example 2-4	×	○	×
Working Example 2-5	×	×	×
Working Example 3-1	○	○	○
Working Example 3-2	○	○	○
Working Example 3-3	○	○	○
Comparative Example 1	×	×	×
Comparative Example 2	×	×	×
Comparative Example 3	×	○	×

[0128]

As shown in Table 3, it was found that clock jitter, the data erasing efficiency and the storage reliability were good in each of the optical recording medium samples of Working Example 1 and Working Examples 3-1 to 3-3 and it was confirmed that each of the optical recording medium samples of Working Example 1 and Working Examples 3-1 to 3-3 exhibited good recording characteristics when data were recorded therein at a linear recording velocity of 31.8 m/sec.

[0129]

[TECHNICAL ADVANTAGE OF THE INVENTION]

As described above, according to the present invention, it is possible to provide an optical recording medium that has improved high-linear-velocity data recording characteristics and is simultaneously

improved in data reproduction durability and storage reliability. Further, according to the present invention, it is possible to provide a data optical recording method and a data optical recording apparatus which can record data in an optical recording medium at an extremely high linear recording velocity in a desired manner.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Figure 1]

Figure 1 (a) is a schematic perspective view showing an external appearance of an optical recording medium that is a preferred embodiment of the present invention and Figure 1 (b) is an enlarged schematic cross-sectional view of the part of the optical recording medium indicated by A in Figure 1.

[Figure 2]

Figure 2 is a diagram showing the waveform of a pulse train pattern employed for modulating the power of a laser beam L when data are to be recorded in the optical recording medium 10, where Figure 2 (a) shows a pulse train pattern used in the case of recording a 2T signal or a 3T signal, Figure 2 (b) shows a pulse train pattern used in the case of recording a 4T signal or a 5T signal, Figure 2 (c) shows a pulse train pattern used in the case of recording a 6T signal or a 7T signal and Figure 2 (d) shows a pulse train pattern used in the case of recording an 8T signal.

[Figure 3]

Figure 3 is a diagram showing a data optical recording apparatus 100 for recording data in the optical recording medium 10.

[BRIEF DESCRIPTION OF REFERENCE NUMERALS]

10 ..... an optical recording medium

11 ..... a support substrate

11a ..... a groove

11b ..... a land

12 ..... a reflective layer

13, 15 ..... a dielectric layer

14 ..... a recording layer

16 ..... a heat radiation layer

17 ..... a light transmission layer

17a ..... a light incidence plane

100 ..... a data optical recording apparatus

101 ..... a spindle motor

102 ..... a traverse motor

103 ..... a laser driving circuit

104 ..... a lens driving circuit

105 ..... a controller

105a ..... a focus controlling circuit

105b ..... a tracking controlling circuit

110 ..... an optical head

111 ..... a laser source

112 ..... a collimator lens

113 ..... a beam splitter

114 ..... an objective lens

115 ..... an actuator

116 ..... a photodetector

L ..... a laser beam